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72-HOUR OPERATING TEST OF A PACKAGED HEAT RECOVERY INCINERATOR.(U)

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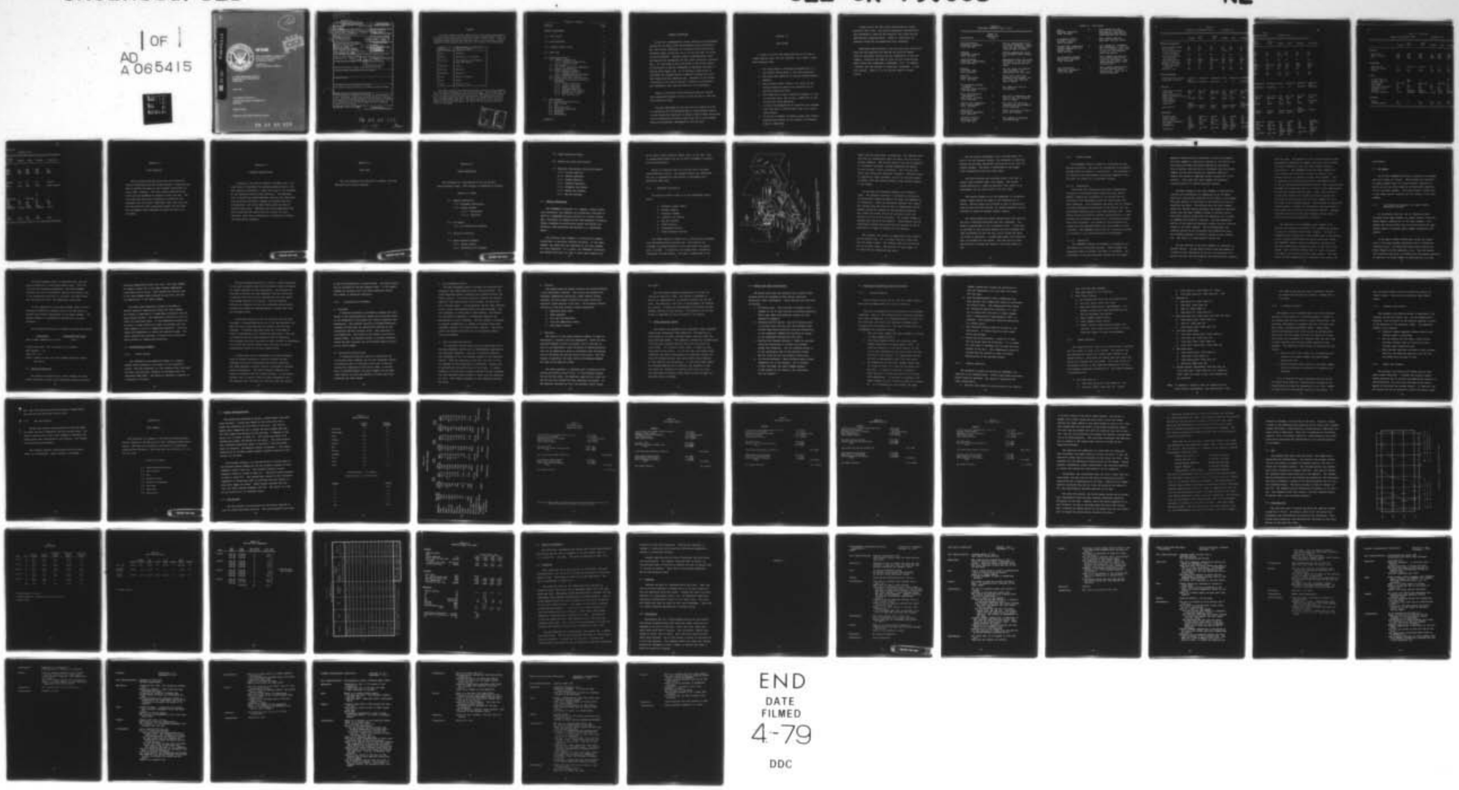

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CIVIL ENGINEERING LABORATORY
Naval Construction Battalion Center
Port Hueneme, California

Sponsored by
NAVAL MATERIAL COMMAND

72 HOUR OPERATING TEST OF A PACKAGED HEAT RECOVERY INCINERATOR

August 1978

An Investigation Conducted by
SYSTEMS TECHNOLOGY CORPORATION
Xenia, Ohio

N68305-77-C-0037

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The performance of the North Little Rock, AR, municipal heat recovery incinerator installation was monitored over a 4-day period. The average energy contents of the solid waste, as fixed, was 3800 Btu/lb. The average conversion efficiency over the 4-day period was found to be 50.7% based upon the low heating value of the solid waste.

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FORWARD

The high heating values (HHV) of the solid waste constituents, on a dry basis, given in American National Standard (ANS) Z228, Incineration, February 1975, have been used in this report. Some adjustments made to match the ANS description of solid waste constituents with the descriptions used in this report are given below:

Report Description	ANS Z228 Description and Source of HHV
Food	Garbage
Garden	69% Grass, 31% Greens
Plastics	44% Plastics, 37% Rubber, and 19% Leather
Textiles	Rags
Ferrous	Metallic
Aluminum	Metallic
Glass	Glass & Ceramic
Inert	Rocks
Fines	Unclassified

The most interesting observation made during the test program was the energy contents of the as fired waste. The average Btu contents of the as fired municipal waste was 3800 Btu/lb, with deviations of about $\pm 3.5\%$ from the average over the 4-day test period. This measured value was about 24% below the 5000 Btu/lb estimate given in ANS Z228, page A-8. The Btu contents on a dry basis of 5327 Btu/lb was approximately 16% below the 6314 Btu/lb estimate given in ANS Z228.

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GENERAL BACKGROUND

As part of a comprehensive Energy Research and Development Program for the Naval Shore Establishment being performed at CEL, the current technology for recovering heat energy from relatively small quantities (10 to 50 tons per day) of refuse is being evaluated. Analysis based on manufacturers' data and typical cost parameters for Navy shore activities indicates that: (1) the value of heat recovered is the primary means of paying back a capital investment in equipment involved in burning solid waste, and (2) to realize a good return on investment the systems must be loaded with refuse fuel more than eight hours per operating day. Shutdown of the furnace (incinerator) for routine periodic cleanout or maintenance more frequently than once per week will be unacceptable.

There is relatively little operating data for systems with capacities between 0.5 and 2.0 tons per day or 1000 and 5000 pounds per hour.

The data generated by this test will be used by the CEL in evaluating the cost-effectiveness of using systems similar to that tested for recycling of refuse at Naval shore facilities, and in establishing criteria under which use of such systems might be economically implemented by the military.

SECTION 1.0

SITE VISITS

In order to fulfill the specifications of the RFQ, a rather specific test site was required. As a review, those specifications were:

1. The system must be continually operated for a 72 hour period during which it was being monitored.
2. The system was comprised of factory prefabricatable modules.
3. Heat recovery either steam or hot water and ash removal capability were to be installed and in operation during the test.
4. The system was to have a capability between 0.5 and 2.0 tons per hour, and to have a capability of controlling the stack emissions.
5. It was to be designed for an auxiliary fuel consumption less than 1.5 million Btu's per ton of solid waste burned.
6. It was to be capable of burning refuse fuel without preprocessing except for the removal of offending items or components.

A phone survey was the initial method used to locate potential test sites. The various incinerator manufacturers were contacted to identify the potential test sites and the manufacturers cooperativeness. Table 1-1 identifies the suppliers contacted and summarizes their responses.

Based upon these contacts, only six units were identified which had the potential for meeting the criteria needed. Since an additional criteria was the cooperation of the host company, a decision was made to visit all six installations. These visits were conducted in September, 1977. In October, a Farrier unit was located in Crossville, Tennessee. It was also visited. Table 1-2 is an outlined report of these visits.

TABLE 1-1
SUPPLIERS CONTACTED (July, 1977)

Manufacturer	Number of Appropriate Sites	
Kelley/Hoskinson Milwaukee, Wisconsin (414) 352-1000	1	Several appropriate units are being installed. Other units are not burning the required type of waste.
Consumat Richmond, Virginia (804) 746-4120	3	Several appropriate units are presently being installed.
Comtro-Sunbeam Landsdale, Pennsylvania (215) 699-4421	1	Appropriate units are being installed, or are not burning the required type of waste.
Enercon Cleveland, Ohio (216) 267-0555	0	All our units are specialized equipment, not appropriate for this test.
Burn-Zol Dover, New Jersey (201) 361-5900	0	These units don't have automatic ash removal, and don't burn the required type of waste.
Environmental Control Products Carlotte, North Carolina (704) 588-1620	1	One other unit may be appropriate.
Basic Environmental Engineering Glen Ellyn, Illinois (312) 469-5340	0	One unit in operation, but doesn't burn the required type of waste.
Farrier Inc.-Smokatrol York, Pennsylvania (717) 767-6717	0	The first two units are proposed and are presently being installed.
Econo-Therm Minnetonka, Minnesota (612) 938-3100	0	These units have no automatic ash removal.
Schaefer Brothers Cleveland, Ohio (216) 621-2112	0	The company is Consumat representatives.

TABLE 1-1 (Continued)

Trane Lacrosse, Wisconsin (608) 782-8000	0	This company is just starting in solid waste incineration, and will be using modified ECP design.
CE Raymond Division Chicago, Illinois (312) 236-4044	0	This company does not make heat recovery units.
Midland Ross Corporation Surface Combustion Div. Toledo, Ohio (419) 537-6176	0	This companies' customers are confidential. The test unit is in their plant, but it can only be tested by their own people.
Air Preheater Company Wellsville, New York (716) 593-2700	0	This company has been out of the incinerator business for two years. They never manufactured a heat recovery unit.
AFB Contractors Martinez, California (415) 229-3400	0	This company manufacturers no heat recovery solid waste units. They are in the RDF business.

TABLE 1-2

SUMMARY OF INCINERATOR VISITS September, 1977

	Rockwell	John Deere	Little Rock	Diamond	Moore	Pentagon
CONTRACT REQUIREMENTS:						
Factory prefabricatable	yes	yes	yes	yes	yes	yes
Heat recovery	yes	yes	yes	yes	yes	yes
.5 to 2.0 TPH capacity	.6	1	1	.7 est.	.5	.6
Aux fuel required $<1.5 \times 10^6$ Btu/ton	yes	yes	yes	yes	yes	no
Burn refuse with no preprocessing	yes	yes	yes	yes	yes	yes
Fuel characteristics	wood	Type 0	municipal	wood	paper	paper
Sufficient material	yes	yes	yes	yes	yes	no
Automatic ash removal	yes	yes	yes	no	no	yes
72 hour continuous operation	no	no	yes	yes	yes	no
Willing to test	yes	no	yes	yes	yes	yes
SYSTEM PARAMETERS:						
Incinerator Mfg. (# Units)	Kelley(1)	Consumat(3)	Consumat(4)	ECP(1)	Comptrol(1)	Consumat(
Boiler Mfg. (# Units)	York Shipley(1)	CRS-805(3)	CRS-1005(2)	- (1)	- (1)	CRS-804(1
OPERATION:						
Installation completed	May 1977	May 1977	Sept. 1977	1975	Feb. 1977	Jan. 1977
Refuse type	wood	Type 0	municipal	wood	Type 1	paper
Refuse capacity (TPH)	.6	1	1	.7 est.	.5	.6
Operating schedule (Hr/Day)	12	12	24	24	24	8
Output form	hot water	steam	steam	steam	steam	steam
Output capacity (10^6 Btu/Hr)	-	-	9	9	-	7
Output use	space condition	process	process	process	process	space conditio
Ash condition	green	green	green	white	white	white
INCINERATOR:						
Auxiliary fuel	oil	waste oil	oil/gas	oil	oil/gas	oil
Refuse injection	ram	ram	ram	ram	ram	ram
Refuse transfer	none	two rams	two rams	ram	none	ram
Ash removal (automatic)	ram	ram	ram	fall	fall	ram
Ash quench	spray	spray	water pit	spray	spray	water pi
Underfire air	primary floor	ram tubes	ram tubes	primary floor	primary floor	ram tube
Overfire air	no	no	no	yes	yes	no

2

TABLE 1-2

CINERATOR VISITS September, 1977

John Deere	Little Rock	Diamond	Moore	Pentagon	Crossville
yes	yes	yes	yes	yes	yes
yes	yes	yes	yes	yes	yes
1	1	.7 est.	.5	.6	1
yes	yes	yes	yes	no	yes
yes	yes	yes	yes	yes	yes
Type 0	municipal	wood	paper	paper	mixed
yes	yes	yes	yes	no	yes
yes	yes	no	no	yes	no
no	yes	yes	yes	no	yes
no	yes	yes	yes	yes	yes
Consumat(3)	Consumat(4)	ECP(1)	Comptrol(1)	Consumat(1)	Farrier(2) York
CRS-805(3)	CRS-1005(2)	- (1)	- (1)	CRS-804 (1)	Shipley(2)
May 1977	Sept. 1977	1975	Feb. 1977	Jan. 1977	Jan. 1978
Type 0	municipal	wood	Type 1	paper	mixed
1	1	.7 est.	.5	.6	1
12	24	24	24	8	24 hr/day
steam	steam	steam	steam	steam	steam
-	9	9	-	7	6
process	process	process	process	space condition	process
green	green	white	white	white	-
waste oil	oil/gas	oil	oil/gas	oil	oil/gas
ram	ram	ram	ram	ram	ball screw
two rams	two rams	ram	none	ram	none
ram	ram	fall	fall	ram	fall
spray	water pit	spray	spray	water pit	water pit
		primary	primary		primary
ram tubes	ram tubes	floor	floor	ram tubes	floor
no	no	yes	yes	no	yes

TABLE 1-2 (Continued)

SUMMARY OF INCINERATOR VISITS September, 1977

	Rockwell	John Deere	Little Rock	Diamond	Moore	Pentago
CONTROLS:						
Quench water	temp	temp	temp	no	temp	temp
Refuse injection	time	time	time	temp	temp	time
Air	temp	temp	temp	temp	temp	temp
AFTERBURNER:						
Auxiliary fuel	oil	waste oil	oil/gas	oil	oil	oil
Excess air blower	-	2	2	-	-	2
Control	temp	temp	temp	temp	temp	temp
BOILER:						
Initial steam (^{o}F)	-	900	-	-	-	600
Automatic dump (^{o}F)	-	1800	-	-	-	-
Configuration	fire tube	-	water tube	-	fire tube	-
Soot blower	no	yes	yes	no	-	yes
Condensate preparation	yes	yes	yes	yes	yes	no
Condensate return	yes	no	50%	no	yes	no
Blowdown	-	automatic	manual	-	daily	daily
ID fan or aspirator	ID fan	aspirator	aspirator	ID fan	ID fan	aspirato
EMISSIONS:						
Tested	no	no	no	no	no	yes
Problems expected	none	-	none	none	none	none

2

(Continued)

September, 1977

Little Rock	Diamond	Moore	Pentagon	Crossville
temp	no	temp	temp	no
time	temp	temp	time	temp
temp	temp	temp	temp	temp
oil/gas	oil	oil	oil	oil/gas
2	-	-	2	1
temp	temp	temp	temp	oxygen analyzer
-	-	-	600	-
-	-	-	-	-
water tube	-	fire tube	-	-
yes	no	-	yes	no
yes	yes	yes	no	yes
50%	no	yes	no	none
manual	-	daily	daily	-
aspirator	ID fan	ID fan	aspirator	ID fan
no	no	no	yes	-
none	none	none	none	none

SECTION 2.0

SITE SELECTION

From the data collected during the site visits and further discussions with the Project Monitor, a decision was made to perform the tests on the Consumat installation at Little Rock, Arkansas. This unit burned mixed municipal refuse and was scheduled to operate 24 hours per day. The City officials were very interested in having the test performed, and of no small importance, were very sure that the unit would be fully operational before the test date. The arrangements were completed to allow the test to be performed.

SECTION 3.0

OPTIMUM LOADING RATES

Originally, the project schedule included a set of in-plant tests to determine the optimum operating rate of the heat recovery incinerator. These tests were to be conducted by the operators during normal operation. The operators were to record the steam production and vary the load rates. This would have provided a measure of optimum load rate. Unfortunately, the Little Rock Facility was not able to perform these tests. Debugging and tuning operations were being performed just before and even during the test. Therefore, there was no opportunity to perform the loading rate analysis as proposed.

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SECTION 4.0

TEST PLAN

The test protocol was completed in October, 1977 and approved by the Project Monitor.

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SECTION 5.0

PLANT DESCRIPTION

The following is a description of the Little Rock Energy Recovery Plant. This section is organized as follows:

Section 5.0 Index

5.1 General Description

5.1.1 Equipment Description

5.1.2 Design Concept

5.1.2.1 Background

5.1.2.2 Operation

5.2 Air Supply

5.2.1 Air Modulation Operation

5.3 Overfire Protection

5.4 Steam Production Module

5.4.1 Design Concept

5.4.2 Description of Equipment

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5.5 Flame Protection System

5.6 Burner Fuel Train and Controls

5.7 Municipal Incineration Start-Up Procedure

5.7.1 Initial Start-Up

5.7.2 General Operation

5.7.3 Loader Operation

5.7.4 Burndown Operation

5.7.5 Automatic Ash Ejector

5.7.6 Manual Ash Cleanout

5.7.7 Wet Ash Conveyor

5.1 General Description

The CONSUMAT® incinerator is a compact, factory assembled incinerator that employs IIA (Incinerator Institute of America) recommended velocity profiles in a novel arrangement, that meets or exceeds all EPA (Environmental Protection Agency) standards for particulate matter and noxious gas emissions, when maintained and operated in a responsible manner.

The grateless lower chamber, or distillation chamber, volatilizes, or partially oxidizes the waste. In the upper chamber, the gases that are generated in the lower chamber are fully combusted. As a result, the CONSUMAT® incinerator can consume from Type 0 to Type 6 waste, when properly set

up for each, without emitting smoke, odor, or fly ash. This is accomplished without the use of water scrubbers or electrostatic precipitators.

Energy is recovered from the flue gas with a matched, steam production module. The system controls are integrated. The unit is designed and constructed in accordance with applicable ASME codes.

5.1.1 Equipment Description

The overall system is made up of the subsystems listed below:

a. Automatic Loader (dual)
b. Primary Chamber
c. Secondary Chamber
d. Automatic Ash Ejector
e. Wet Ash Conveyor
f. Stack Sections
g. Integrated Controls
h. Steam Production System

The loader employs a hopper with a hydraulically operated door and hydraulically operated ram. The controls are arranged to prevent operation of the ram unless the hopper door is closed. In operation, the hopper door is opened by depressing the Open Button. The waste is deposited in the

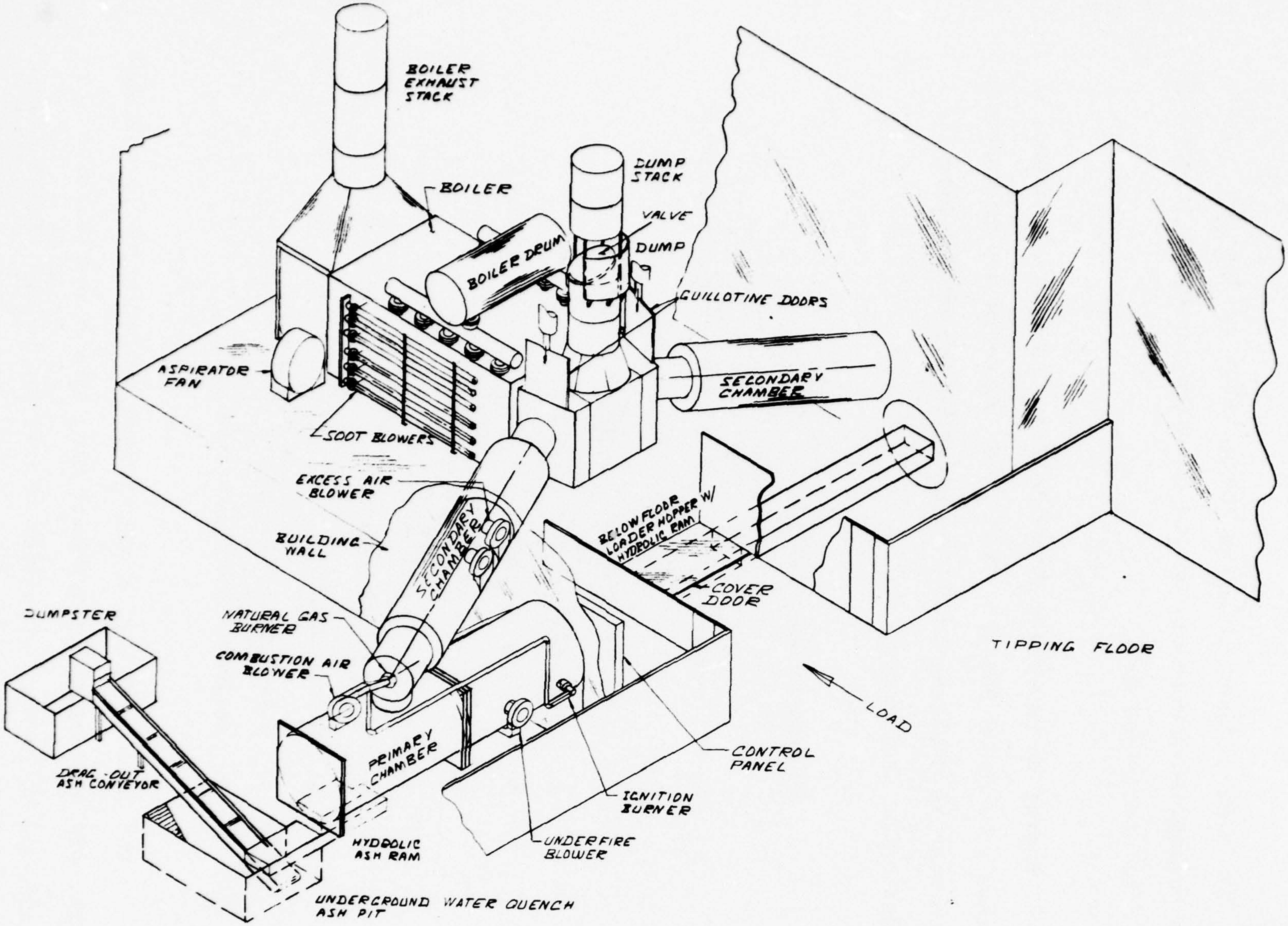

Figure 5-1. CONSUMAT ® Packaged Heat Recovery Incinerator, Located at Little Rock, Arkansas.

hopper and the Load Button is depressed. The controls then take over to automatically feed the waste into one of the primary chambers. The driving force of the ram is supplied by a hydraulic cylinder, located underneath the loader, driving through a cable arrangement. The fire door and hopper are raised with hydraulic cylinders. Hydraulic fluid is supplied to these cylinders, as well as the ash ejector cylinders, from the central hydraulic pump located adjacent to the loader.

The primary and secondary chambers are refractory lined. The castable refractory is anchored in place with stainless steel hangers welded to the shell and embedded in the refractory. Since the refractory material will expand and contract with the rise and fall of temperature, minute thermal cracks will develop in the refractory material. Such cracks are normal and do not adversely affect the operation or life of the equipment. The primary chamber is equipped with two dual fuel burners. These burners utilize electrically ignited gas pilots and will operate on gas or distillate oil fuels as selected by the operator.

The automatic ash ejector is comprised of two internal and one ejector ram. Each of these rams will cycle each time the loader cycles. The internal rams are fitted with two air injector tubes. The function of these tubes, is to inject the air underneath the waste.

The ash ejector discharges into a wet sump which is a part of the ash conveyor system. The discharge is below the surface of the water preventing infiltration of air into the primary chamber. The water is maintained at the proper level automatically with the float valve.

The stack sections are stainless steel, four feet in length, with standard angle ring flanges. The overall system operates at a negative pressure; thus, there is no requirement for the stack joints to be gas tight.

The control system of all the components is integrated. Signal lights signify the mode of each operation as it occurs. Warning lights are provided in case of malfunction. Once the unit has been started, the loading operation can be achieved by using the pendant control station.

The steam production module extracts heat from the flue gas with a waterwall-watertube type heat exchanger. One module is manifolded to two incinerator units. A fire door is provided in the breeching between the heat exchanger and each incinerator so that one unit can be closed off while the other is operating. A single dump stack, with close-off cap, is provided for the system. The flue gas will automatically exit through this stack if the steam system is off.

5.1.2 Design Concept

The CONSUMAT® design is based on controlled air combustion principles. The units are engineered, pre-packaged systems which are modular in construction. The equipment is not subject to the performance limitations imposed by conventional (or excess air) incinerator systems.

5.1.2.1 Background--

Controlled air incinerators were first commercially available in the United States during the early 1960's. However, substantial acceptance of the concept was not reflected in the marketplace until the late sixties and early seventies. This acceptance was mostly due to a demand for high performance incineration in the form of very low particulate emissions and a very high reduction rate. These factors are anti-pollution features characteristic of a well designed and engineered controlled air incineration system. Since this acceptance, the success of the controlled air concept has been demonstrated by the large number of units installed. The CONSUMAT® controlled air incineration system is currently in its third generation of development.

5.1.2.2 Operation--

The CONSUMAT® employs two chambers to accomplish the controlled air incineration process. These chambers are designated lower or primary, and upper or secondary. The performance of the anti-pollution features of the system

depend on controlling the conditions in these two chambers. The lower chamber is required to operate at low interior gas velocities and under controlled temperature conditions. This is done by limiting the air introduced into the primary chamber to less than required for complete combustion. (Hence, the system is sometimes called "starved air" incineration). This gives the lower chamber the operating characteristics of a partial pyrolysis system.

The heat release in the lower chamber is controlled by limiting the introduction of combustion air to an amount which will give partial oxidation of the waste in the chamber. This heat release is sufficient to self-sustain the partial oxidation reactions. The effluent from the lower chamber, which will include various pyrolytic and oxidative compounds, passes into the upper chamber through a turbulent mixing zone where ignition takes place and additional air is added to complete the oxidation reactions. The non-combustible portion of the waste and carbonous residue from the reactions remain in the lower chamber. The non-combustibles are rendered sterile by the relatively high temperature while the carbonous material is further oxidized by the incoming air. The result is a high quality sterile ash.

The gas velocity in the lower chamber is influenced by several factors. The gas which evolves from the chamber is a result of the interaction of the air, the auxiliary fuel during start-up, and the oxidation and volatilization products

from the waste. The quantity of gas from the waste can vary substantially depending on chamber conditions and the waste and would, therefore, alter the lower chamber velocity significantly. The CONSUMAT® upper and lower chamber air flow controls are integrated in order to minimize this peaking activity to provide a uniform flow of gases. This is important for controlling pollution performance as well as for an efficient energy recovery system. When volatilization proceeds at an excessive rate as a result of high temperatures, two distinct adverse effects occur. First, the velocities in the lower chamber will exceed the design velocity and particles will be carried into the upper chamber which are too large to be oxidized properly. This process is essentially uncontrollable in excess air incinerators and contributes to their inability to maintain low pollution exhaust. Secondly, the gases will flow to the upper chamber and can result in excessive particulate emissions or smoking.

The function of the CONSUMAT® upper chamber is to complete the oxidation reactions of the combustible products as they are received from the lower chamber. In order to accomplish this, conditions in the chamber must be controlled within a rather narrow band from inputs which vary widely. The CONSUMAT® control system is designed to maintain the required conditions by modulating both air and fuel to the system. This in effect controls the air input, auxiliary fuel input, and gas flow from the lower chamber. The modulation is done automatically in accordance with factory set

requirements.

5.2 Air Supply

The CS-1200 CONSUMAT® municipal incinerator is equipped with four forced air blowers. Three blowers are located on the upper chamber where one (high pressure) supplies all burner air and the other supplies the modulated combustion air for the upper chamber. The fourth blower (located next to the loader tap-in) supplies the air plenums on the lower chamber.

5.2.1 Air Modulation Operation (For Upper Chamber Temperature Control)

At incinerator start-up, the air modulation motor (located on the upper chamber air supply blower) closes the blower damper, reducing air to the upper chamber. This reduces the cooling effect the air has and allows the upper chamber burner to increase upper chamber temperature more rapidly.

As the upper chamber thermocouple senses the temperature in the upper chamber approaching the air modulation controller point, the modulation motor begins opening the blower damper with the temperature rise. When the modulation controller set point is reached with incinerator operating at capacity, the blower damper is approximately full open.

The upper chamber burner is modulated down, and ultimately turned off, as the blower damper opens. With the fuel off and increasing temperature, the lower chamber underfire air will be decreased, reducing the burning rate. If the temperature continues to increase, the lower blower will be turned off until the temperature stabilizes.

If the temperature in the upper chamber drops, the air modulation system will modulate the air and the burner to maintain the correct temperatures in the upper chamber. The primary chamber is independently modulating to maintain pyrolysis.

The following settings are suitable for most applications.

APPLICATION	TEMPERATURE SET POINT
Upper Chamber Temperature Control	1700°F

Proportional Band - Set 15 percent to 20 percent

Rate Minutes - .04

Reset R/M - 10

Alarm - Adjust to shut off lower chamber blower 50° above set point.

5.3 Overfire Protection

The system is equipped with a lower chamber air modulation system and a water spray moderation system to prevent

excessive temperatures within the unit. The lower chamber air supply is shut off if the upper chamber temperature rises above the set point. This reduces the reaction rate in the lower chamber which reduces the gas flow, and thus the temperature, to the upper chamber.

The water spray moderation system is provided to prevent excessive temperatures within the lower chamber. The system is comprised of a temperature controller and two spray nozzle systems. The temperature controller is set for 1800°F for municipal waste. If the temperature exceeds the set point, a small quantity of water is atomized into the lower chamber to act as a temperature moderator. This will reduce the temperature to within the operating range. The water solenoid valve provides a constant drip through the spray nozzles for temperature protection.

5.4 Steam Production Module

5.4.1 Design Concept

The CONSUMAT® steam production module is a compact modular design matched to the output of the incinerator system. The heat exchanger is a low pressure drop, watertube-waterwall configuration, designed in accordance with the applicable ASME codes. The system is designed to operate at a pressure of 150 psig.

The heat recovery system will recover a large percentage of the heat released within the incinerator without affecting the normal operation of the incinerator. The controls are designed to protect the heat exchanger from the variations in burning rates and flue gas temperatures that can result from random loading of the system. The heat recovery controls are designed so that the incinerator may be easily operated to produce the maximum amount of useful heat from the available waste.

Directional control of the hot flue gas into the heat exchanger is accomplished by use of a flue gas aspirator and does not rely on the operation of valves in the flue gas passages. A normally open dump stack cap is provided to insure a minimum heat loss through the dump stack. This cap is closed during the steam production mode of operation. This promotes fail-safe operation as power failure or malfunction of the flue gas control system allows the hot flue gas to automatically return to the heat dumping stack.

A baffle-type valve is provided in the heat exchanger stack to prevent backflow of cold air through the heat exchanger during the incinerator-only mode of operation. The steam separator pressure control is designed to prevent system overpressure. The actual delivery pressure will depend on recovery rate and system pressure. If the energy recovery rate is greater than the steam consumption rate, the pressure will rise and will cycle the flue gas control

on and off automatically to match demand. The excess energy will be rejected to the heat dumping stack. If the demand exceeds the recovery rate, the steam production system will remain in operation constantly.

5.4.2 Description of Equipment

A. Structure

A structural platform is provided to support the full weight of the steam production module and to provide access to all components of the module for routine inspection and maintenance. The platform consists of prefabricated bolt-together sections that are specifically matched to the incinerator and heat recovery units. This structure is self-supporting. The weight of the system is carried by support beams. The package provides a platform extending around the heat recovery unit and includes safety railing and an access ladder.

B. Refractory-Lined Sections

A refractory-lined tee section is mated with the incinerator upper chambers and the heat exchanger section. An inspection door is provided on the side of the tee section for inspection of the boiler tubes. A shutoff door is provided between the upper chamber and the dump stack section to allow one system to be shut down while operating the other system.

C. Heat Exchanger Section

The heat exchanger section includes the watertube heat exchanger, the steam separator drum, and soot blower. The steam separation drum is equipped with standard control and safety devices. The control provides contacts for pump-on, pump-off, high and low water level alarms, low water cut-off, and sight glass. A high pressure cut-off, dual pressure relief valves, and blowdown drains are also provided. The heat exchanger is fabricated in tube modules. The modules are individually removable if ultimately required, for maintenance or repair purposes. The soot blower is designed to operate automatically as needed to maintain clean heat exchanger surfaces for efficient heat transfer. The design allows the overall efficiency to be increased by adding additional modules.

D. Flue Gas Aspirator Section

The aspirator section mates with the downstream end of the heat exchanger section and is independently supported on the structural platform. Flue gas is pulled through the heat exchanger by the low pressure created in the aspirator section. When the aspirator is cut off, the flow of flue gas through the heat exchanger is terminated. Reverse flow is prevented by the baffle valve in the stack. In normal operation, the flue gas is pulled through the heat exchanger into the aspirator section where it mixes with the aspirator jet flow. This mixture exhausts to the atmosphere through the stack.

E. Controls

The steam production module controls are located adjacent to the incinerator controls. The control box contains the necessary temperature controllers, water control relays, switches, and soot blower controls with power switch and indicator lights mounted in the door. The principle control functions of the heat recovery control system are:

1. Separator water level
2. Steam pressure
3. Flue gas flow direction
4. Flue gas temperature limits
5. Soot blower cycling

F. Operation

The control of the steam production module is based on maintaining a constant flue gas temperature. Since the heat extracted depends on both the weight flow of flue gas as well as its temperature, some variations of steam production rate can be expected to occur in accordance with the burning rate of the waste and the Btu value of the waste. Once the system is operating, the water level will modulate between the pump-on and pump-off levels.

The steam separator is equipped with a pressure cut-off switch and pressure relief valve. If the pressure reaches the cut-off set point, the aspirator pump will be turned off and the gas flow through the heat exchanger terminated. If the pressure continues to rise, the pressure relief valves

will open.

The soot blower operates automatically to clean one section of tubes at a time. The system is designed to operate on compressed air at pressures between 150 and 200 psig. The duration of the blow is approximately two seconds per section. A period of approximately five minutes elapses between the blow of each section. The operation of the soot blower is important to the efficiency of the system.

5.5 Flame Detection System

The burners are equipped with a Honeywell flame safeguard system with ultraviolet flame detectors. The function of this system is to safely initiate burner ignition after the pilot has been proven. This detection system will automatically call for spark ignition and open the pilot gas valve for pilot flame. If it detects pilot flame, it opens the main fuel valve to the burner. If, at any time, the burner flame should be lost due to malfunction, the detection system will turn off (close) the main fuel valve within three seconds. It will then try for re-ignition. If the pilot flame cannot be re-established within 30 seconds, the protection relay will kick out, turning off (closing) the pilot gas valve. The relay must be manually reset before another attempt for ignition can be initiated.

5.6 Burner Fuel Train And Controls

The burner fuel train and controls have various safety features which are designed to meet Factory Insurance Association (FIA) requirements. These features are described as follows:

a. Pre-Purge Cycle - This provides a minimum of four changes of air at each start-up to provide protection due to gas leaks from defective valves into the combustion chambers.

b. Blocking and Vent Valves - The two blocking valves on the gas train with the vent valve between them provide additional protection from gas accumulating in the combustion chambers by providing an escape to the atmosphere through the vent valve.

c. High and Low Pressure Switches - These two switches allow the incinerator to operate only between preset fuel pressures. The low pressure switch is on the incinerator side of the blocking valves. The oil train has the low pressure switch only.

d. Air Proving Switches - These switches assure proper combustion air to the burners. One is located on both the upper and lower chamber blowers. If the blowers do not operate, the incinerator will not operate.

5.7 Municipal Incinerator Start-Up Procedure

5.7.1 Initial Start-Up

The refractory curing and air and fuel supply adjustments will be made during the initial start-up.

The unit is shipped with the refractory in the uncured condition. That is, the refractory still contains moisture which must be baked out in a controlled manner in order for the refractory to develop full physical characteristics designed into the formulation. The steps listed below are recommended for refractory curing:

a. Shut off lower chamber and upper chamber air except to lower chamber burners.

b. Fire lower chamber burners to raise the lower chamber temperature to approximately 400°F. It might be necessary to run these burners for one to two days depending on the size of the unit and capacity of the burners. The temperature should be held at approximately 400°F for five hours.

c. The temperature in the lower chamber should then be raised to 1000°F at a rate not to exceed 50°F per hour. It might be necessary to charge a small quantity of waste into the unit to achieve this temperature. If charging is necessary, the upper chamber air will eventually need to be turned on. It is necessary to also control the upper

chamber temperature through the controller so that the temperature rise rate does not exceed 50°F per hour.

d. Once the approximately 1000°F temperature has been reached, this temperature should be maintained for several hours. The temperatures then should be increased by additional charging, at a rate not to exceed 100°F per hour in either chamber until a temperature of approximately 1800°F is attained. This temperature should be maintained for several hours.

e. The refractory should always be allowed to cool down slowly. All doors should be kept closed during the process.

f. During the curing process, a quantity of water will be driven from the refractory. It is common for this water to condense and run down the outer surface of the unit. This condensation should be cleaned from the surface in order to prevent deterioration of the painted surface.

5.7.2 General Operation

The procedure is basic to putting the CONSUMAT® into operation on an everyday basis. Overall good safety practices should always be observed. The system is started by the steps listed below:

1. Position fuel valves to correct position for desired

fuel (for dual fuel systems).

2. Turn power switch to "on" position.
3. Push "start" button.
    a. All blowers will start for pre-purge period.
    b. Main fuel safety valve will open.
    c. After pre-purge period, approximately 1 1/2 minutes, pilots will light provided the fuel and air pressures have proven.
    d. Upper chamber burner starts.
    e. Lower chamber burner starts.
    f. Loader interval timer fulfills preset time interval, and "ready-to-load" light is illuminated and loader is ready to be charged.

5.7.3 Loader Operation

The "ready-to-load" light on the control panel indicates that the loader is ready to be charged. The operator can then momentarily depress the "loader open" button on the pendant station. This opens the hopper door and allows the waste to be charged into the loader. The "load" button on the pendant station is then depressed momentarily and the load sequence progresses automatically. The loading sequence is outlined below:

1. Fire door goes up.
    a. "Fire door going up" light comes on - red.
    b. "Fire door down" light goes off - green.

c. "Fire door up" light comes on - green.

d. "Fire door going up" light goes off - red.

2. Ram goes in.

a. "Ram going in" light comes on.

b. "Ram back" light goes off.

c. "Ram in" light comes in.

d. "Ram going in" light goes off.

3. Ram comes back six inches past fire door and stops.

a. "Ram coming back" light comes on.

b. "Ram in" light goes off.

c. "Ram coming back" light goes off.

4. Fire door comes down.

a. "Fire door coming down" light comes on.

b. "Fire door up" light goes off.

c. "Fire door down" light comes on.

d. "Fire door coming down" light goes off.

5. Ram comes back.

a. "Ram coming back" light comes on.

b. "Ram back" light comes on.

c. "Ram coming back" light goes off.

d. Hydraulic pumps turn off.

6. Eleven minutes (adjustable) from the time the "fire door down" light comes on, the "ready-to-load" light will come on and a new sequence may be initiated.

NOTE: If sequence 1 through 5 does not complete within three minutes (adjustable), the "Malfunction" light

will come on and the unit must be manually operated to correct the malfunction--usually a jammed ram or fire door.

5.7.4 Burndown Operation

The purpose of the burndown mode is to allow automatic shutdown of the system in a controlled manner if waste is not charged into the unit within a preset time period. The municipal incinerator is equipped with two, five-hour automatic reset, adjustable burndown timers. These timers operate continuously after start-up and are automatically reset each time the loader fire door is opened and closed. This allows the incinerator to shutdown after the last load of waste each day with nothing further required of the operator. The functions listed below are controlled by the timers:

a. When the first timer times out, the modulated air blower on the upper chamber and lower chamber blower turn off.

b. When the second timer times out, the upper chamber burner and blower are turned off to complete the shutdown.

If it is desired to begin recharging the unit before the timers have timed out, charging may be resumed in the normal manner provided the temperature in the lower chamber is high enough to re-establish ignition of the waste. If

not, the lower burners can be re-started by pushing the "start" button. This will also reset the lower burner timers.

5.7.5 Automatic Ash Ejector

The automatic ash ejection system is comprised of two internal ram and one ejector ram. All are hydraulically operated. The initiation of the ejection sequence is keyed to the operation of the hydraulic loader. The operating sequence is as follows:

a. Hydraulic loader completes loading function and interval timer is satisfied.

b. The ash ejector ram will make a single stroke and then internal rams will function to move internal ashes toward ash sump.

c. When internal rams have returned to their original position, the hydraulic pump will turn off and the loader will be ready to load.

5.7.6 Manual Ash Cleanout

The automatic ash ejector will handle the ash load under normal conditions. If manual ash cleanout should become desirable due to oversize non-combustible material or some malfunction, the full swing end dome can be easily opened to facilitate the residue removal. In addition, the ash ejector ram can be operated to assist the manual clean-

out. The full swing end dome should not be opened unless the unit has had sufficient time to cool.

5.7.7 Wet Ash Conveyor

The wet ash conveyor system consists of the wet sump, the chain and drive components, and the incline chute. The sump is fitted with a float valve assembly to maintain the proper water level and provision for draining. The flights are pivoted and non-jamming.

The conveyor operates continuously while the incinerator is in operation. Manual control is provided.

SECTION 6.0

TEST SUMMARY

The following is a summary of the data collected during a week of testing at the North Little Rock, Arkansas Refuse Incinerator. The data was collected on the basis of a previously submitted test protocol. The tests were run on May 22, 23, 24, and 25, 1978.

Section 6.0 Index

6.1 Refuse Characterization

6.2 Heat Balance

6.3 Ash

6.4 Auxiliary Fuel

6.5 Electric Consumption

6.6 Emissions

6.7 Down Time

6.8 Maintenance

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6.1 Refuse Characterization

The refuse was collected by taking a random sample from each truck delivery. A point was chosen on the refuse pile and a sample was withdrawn the full depth of the pile. The various samples were composited into a single 500 pound sample each day. The total sample was manually sorted each day. A summary of the manual sort is shown in Table 6-1. The refuse was found to be predominantly paper (49 percent of the total). The other significant categories found were glass (12 percent), food and garden waste (11 percent), and magnetic metals (10 percent). The refuse composition of the whole sample showed a moisture content of 28.6 percent for the week.

The ultimate analysis is a calculated set of values based on the measured refuse composition and the ultimate analysis of each component found in the sort. The ultimate analysis of each composite refuse is listed in Table 6-1. The heat content analysis is shown in Table 6-2. The average heat content of the individual components of refuse were used to calculate the heat content of each day's supply of refuse. These figures indicate that the "dry" Btu (HHV) content averages 5,327 Btu per pound, or 3,800 Btu per pound on an "as received" basis.

6.2 Heat Balance

The heat balance is calculated over the period required to burn the refuse delivered each day. This was necessary since there

TABLE 6-1
REFUSE COMPOSITION

	Percent Total	Percent Moisture
Food Waste	7.0	54
Garden Waste	3.7	65
Paper	48.9	37
Plastics	7.6	17
Textiles	1.4	8
Wood	1.1	13
Ferrous	9.8	6
Aluminum	1.9	6
Glass	12.2	1
Inert	0.4	--
Fines	6.0	33

Moisture Content 28.6 Percent

Ultimate Analysis - Dry Weight Basis

Element	Percent
C	30.6
H_2	4.1
O_2	23.3
N_2	0.5
S	0.2
Ash	40.4

TABLE 6-2

REFUSE HEAT CONTENT

Category	Dry HHV BTU/lb.	M-T 5/22 (lb.) Dry Wt.	M-T 5/22 MBTU	T-W 5/23 (lb.) Dry Wt.	T-W 5/23 MBTU	W-Th 5/24 (lb.) Dry Wt.	W-Th 5/24 MBTU	Th-F 5/24 (lb.) Dry Wt.	Th-F 5/24 MBTU
Food	8484	2678	22.72	4131	35.05	1457	12.36	2616	22.19
Garden	7500	337	2.53	1061	7.96	1803	13.52	1208	9.06
Paper	7572	19435	147.16	32281	244.44	23539	178.23	28637	216.84
Plastics	12194	3587	43.74	8242	100.50	4154	50.65	5247	63.98
Textiles	7652	765	5.85	1407	10.77	1504	11.51	767	5.87
Wood	8613	139	1.20	1286	11.08	579	4.99	1247	10.74
Ferrous	124	7950	0.99	9242	1.15	5571	0.69	8147	1.01
Aluminum	124	0	--	2765	.34	1693	0.21	1480	0.18
Glass	65	9875	0.64	16166	1.05	7766	0.51	6827	0.44
Inert	--	0	--	454	--	633	--	279	--
Fines	3000	2884	8.65	5412	16.24	1441	4.32	3676	11.03
Total Dry Weight		47650		82447		50140		60131	
Total MBtu			233.48		428.58		276.99		341.35
Btu Content Dry			4898 Btu/lb		5198 Btu/lb		5524 Btu/lb		5676 Btu/lb
As Received Refuse Weight		60080		113500		70400		93000	
Btu Content As Received			3886 Btu/lb		3776 Btu/lb		3935 Btu/lb		3670 Btu/lb

TABLE 6-3

HEAT BALANCE SHEET

AVERAGES AND TOTALS

5/22/78 (14:45 hrs) through 5/26/78 (16:37 hrs.)	90.17 hours	
Duration of heat recovery	89.17 hours	
Throughput rate of the incinerator	.93 TPH/incinerator	
Total refuse burned	336980 pounds	
Refuse moisture content	28.6 percent	
Net refuse input*	1,089.6 MBtu	
Auxiliary fuel (11,802 scf natural gas)	12.5 MBtu	
Total	1,102.1 MBtu	
Input during heat recovery (89.19/90.17)		1,091.12 MBtu
Steam produced (486,115 pounds)	574.78 MBtu	
Makeup water (56,860 gallons)	-18.04 MBtu	
Return condensate (3,188 gallons)	-4.19 MBtu	
Total		552.55 MBtu
Net thermal efficiency		50.7 Percent

* Net input = Heat content of refuse, minus the heat to vaporize moisture in waste, and the heat to vaporize water formed by combustion reaction.

TABLE 6-4

HEAT BALANCE SHEET #2

Period 1

5/22/78 (14:45 hrs) through 5/23/78 (03:00 hrs)	12.25 hours	
Duration of heat recovery	12.13 hours	
Throughput rate of the incinerator	1.23 TPH/incinerator	
Total refuse burned	60,080 pounds	
Refuse moisture content	20.7 percent	
Net refuse input	204.41 MBtu	
Auxiliary fuel (944 scf natural gas)	1.00 MBtu	
Total	205.41 MBtu	
Input during heat recovery (12.13/12.25)		203.40 MBtu
Steam produced (80,618 pounds)	95.32 MBtu	
Makeup water (9,660 gallons)	-3.06 MBtu	
Return condensate (11 gallons)	- .01 MBtu	
Total		92.25 MBtu
Net thermal efficiency		45.4 Percent

TABLE 6-5

HEAT BALANCE SHEET #3

Period 2

5/23/78 (10:45 hrs) through 5/24/78 (12:25 hrs)	25.72 hours	
Duration of heat recovery	25.38 hours	
Throughput rate of the incinerator	1.10 TPH/incinerator	
Total refuse burned	113,500 pounds	
Refuse moisture content	27.3 percent	
Net refuse input	365.85 MBtu	
Auxiliary fuel (1180 scf natural gas)	1.25 MBtu	
Total	367.10 MBtu	
Input during heat recovery (25.38/25.72)		362.25 MBtu
Steam produced (156,942 pounds)	185.57 MBtu	
Makeup water (18,810 gallons)	-5.97 MBtu	
Return condensate (17 gallons)	- .02 MBtu	
Total		179.58 MBtu
Net thermal efficiency		49.6 Percent

TABLE 6-6
HEAT BALANCE SHEET #4

Period 3

5/24/78 (12:25 hrs) through 5/25/78 (08:25 hrs)	20.00 hours	
Duration of heat recovery	19.58 hours	
Throughput rate of the incinerator	.88 TPH/incinerator	
Total refuse burned	70,400 pounds	
Refuse moisture content	28.8 percent	
Net refuse input as received	237.04 MBtu	
Auxiliary fuel (2833 scf natural gas)	3.0 MBtu	
Total	240.04 MBtu	
Input during heat recovery (19.58/20.00)		235.0 MBtu
Steam produced (95,982 pounds)	113.49 MBtu	
Makeup water (11,278 gallons)	-3.58 MBtu	
Return condensate (1,969 gallons)	-2.59 MBtu	
Total		107.32 MBtu
Net thermal efficiency		45.7 percent

TABLE 6-7
HEAT BALANCE SHEET #5

Period 4

5/25/78 (08:25 hrs) through 5/26/78 (16:37 hrs)	32.20 hours	
Duration of heat recovery	32.10 hours	
Throughput rate of the incinerator	.72 TPH/incinerator	
Total refuse burned	93,000 pounds	
Refuse moisture content	35.3 percent	
Net refuse input	282.30 MBtu	
Auxiliary fuel (6609 scf natural gas)	7.0 MBtu	
Total	289.30 MBtu	
Input during heat recovery (32.10/32.20)		288.4 MBtu
Steam produced (152,573 pounds)	180.40 MBtu	
Makeup water (17,112 gallons)	-5.43 MBtu	
Return condensate (1,191 gallons)	-1.57 MBtu	
Total		173.40 MBtu
Net thermal efficiency		60.1 percent

is no way to monitor the hourly refuse burned. The refuse is pushed (not lifted) across the floor with a front-end loader because the loader bucket is not large enough to carry a full load. This system does not lend itself to any known monitoring system. The load rate was between four and six loads per hour per incinerator, but was very consistent and steady over specific time periods (up to 16 hours duration). The variations throughout the week were due to changes in the charge timer setting as chosen by the operating personnel.

The underfire and combustion air flows were not monitored. The incinerator air supply control circuits are built so that the electrical signal has no correlation to the actual air flow. They indicate only the opening or closing motion of the damper. Adding pressure transducers, signal conditioners, and recording apparatus to record the varying air flow proved to be too expensive.

Furthermore, the incinerators were not fully "tuned" when the tests began, and the lack of continuous air monitoring greatly complicated the interpretation of the data. Observation of damper position indicated that the air flow, particularly the underfire air, was significantly adjusted each day of the test.

Over this test period, the boiler bypass system was activated very infrequently since the heat recovery system was operating 99 percent of the time. However, while the system appeared to be well balanced, the cap on the dump stack was nearly half burned away, allowing an unknown amount of the heated flue gas and radiant heat to escape the system before reaching the boiler.

The total refuse burned in both incinerators was 168 tons for 1,090 million Btu of input. The auxiliary fuel for this period totaled 12.5 million Btu or 1 percent of the total heat input. There was 486,000 pounds of steam produced during this period. The net thermal efficiency over the week was 50.7 percent. The data sheets following the summary provide data for each heating period during the test.

While each of the periods is unique unto itself, as a group they demonstrate the improvements which result from proper tuning of a system. The following is a summary of the changes in system performance during the week:

Thermal efficiency (%)	32 percent increase
Refuse moisture (%)	70 percent increase
Refuse burned (MBtu/hr)	48 percent decrease
Output (MBtu/hr)	29 percent decrease
Steam output (1,000 lb/hr)	29 percent decrease

The period efficiencies increase from 45.4 to 60.1 percent while the throughput rate decreased from 1.23 tons per hour per incinerator to .72 tons per hour per incinerator. This would tend to indicate that a slower throughput allows better burnout and better thermal efficiency on the units. This is emphasized by the fact that the refuse moisture content increased throughout the week, thus adding additional burden to the unit operation. The auxiliary fuel use increased as the week proceeded, but it only reached a maximum of 2 percent of the total Btu input. The steam usage decreased daily. The net result of all of these changes, plus air flow improvements, was that the thermal efficiency reached a

maximum on Thursday, the last day of the test. Figure 6-1 shows a graph of the normalized data plotting of the natural gas consumed, thermal efficiency, refuse moisture, refuse burned in MBtu/hour and steam output in MBtu/hour. This unit is operating at 100 percent capacity, with a 25 percent variation. Unfortunately, the control optimization prevented the identification of an optimum capacity or throughput.

6.3 Ash

Ash samples were taken every two hours. The samples were composited and screened daily. The material that passed through the one inch screen is called the "passed" portion, the rest is called the "retained" portion. The retained portion was predominately cans, containing 17 percent moisture. This was not tested for unburned carbon since there was no ash apparent. The "passed" portion contained all of the reduced ash produced by the incinerator. This portion showed an average of 45 percent moisture and 18.5 percent unburned carbon. The daily ash data is shown in Tables 6-8 and 6-9. The "passed" portion constitutes 67 percent of the total ash. The composite total ash contains 7 percent unburned carbon, 58 percent inert, and 35 percent moisture.

6.4 Auxiliary Fuel

The auxiliary fuel is natural gas which was supplied through a pipeline at 20 psi. As shown in Table 6-10, the natural gas consumption was consistently low with only two exceptions. Even during those exceptions, the auxiliary Btu increased to only three percent or the total Btu input.

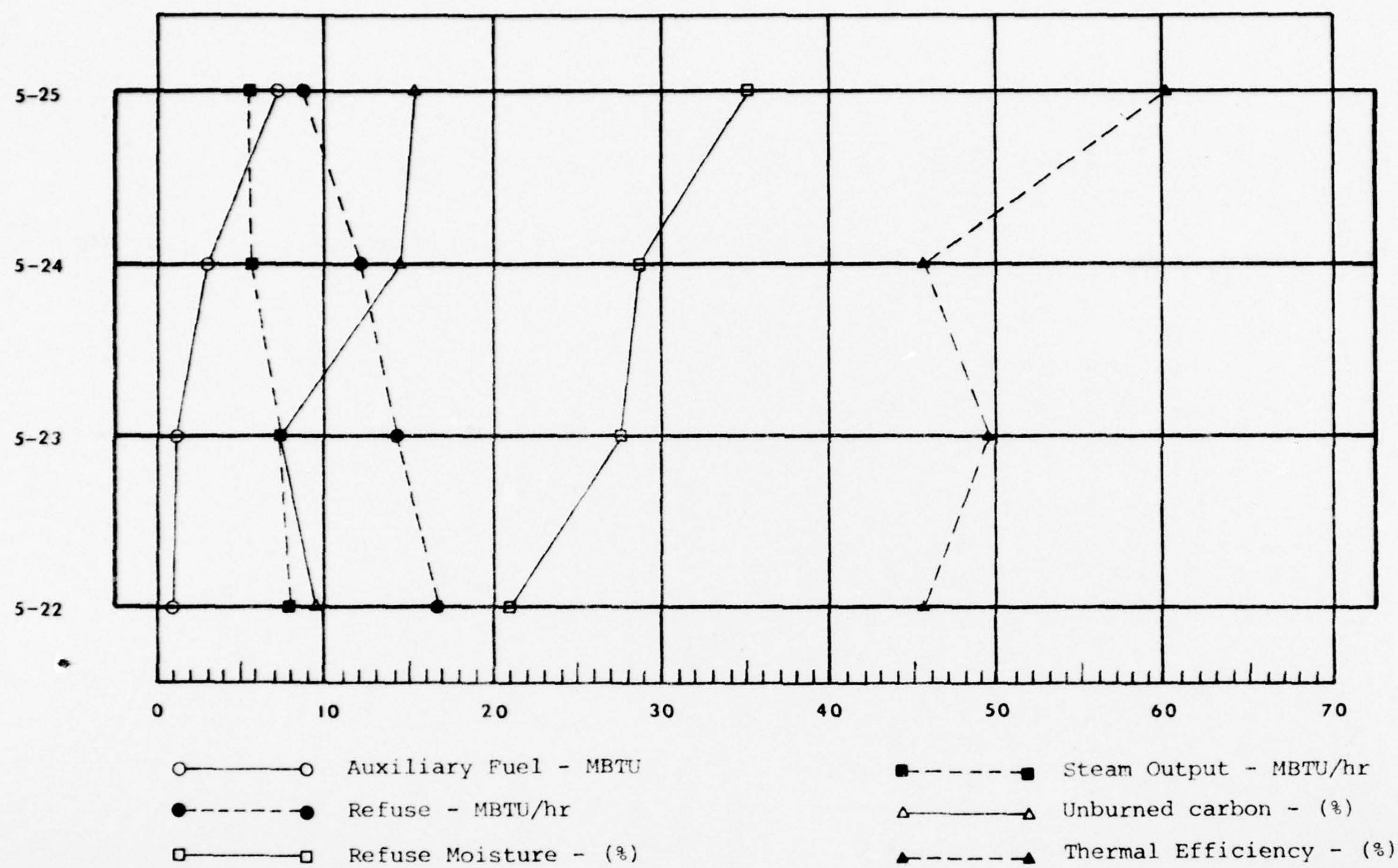

Figure 6-1. Normalized incinerator data.

TABLE 6-8
DAILY ASH DATA

Date	Unit	Percent Retain*	Percent Passed*	Percent H_2O† (Passed Sample)	Percent UC†§ (Passed Sample)	Percent UC§ (Total Dry Sample)
5/22/78	3	29.5	70.5	44.7	15.11	9.3
	4	31.5	68.5	56.0	17.77	9.5
5/23/78	3	34.0	66.0	28.8	12.89	8.0
	4	42.2	57.8	45.2	12.03	5.7
5/24/78	3	31.0	68.4	23.4	26.74	17.8
	4	32.0	68.0	46.6	18.24	10.6
5/25/78	3	26.8	73.2	67.7	25.72	13.3
	4	25.0	75.0	45.4	25.97	17.2
5/26/78	3	41.0	59.0	--	17.23	8.4
	4	40.0	60.0	--	13.50	6.7
	Avg.	33.4	66.6	44.7	18.52	10.7

* Screened through 1 inch sieve

† Retained sample had 17.3 percent H_2O with 100 percent inert

§ Unburned carbon

TABLE 6-9
TOTAL COMPOSITE DATA

	Pounds	Percent of Total	H_2O Weight	Percent	UC* Weight	Percent	Inert Weight	Percent
Total Ash	208,500	100	74,071	35	14,243	7	120,186	58
Retained Portion	69,556	33.4	12,033	17	--	--	57,523	83
Passed Portion	138,944	66.6	62,034	44.6	14,243	10	62,663	45

* Unburned carbon

TABLE 6-10
AUXILIARY FUEL CONSUMPTION

Date	Time Start	Time Finish	Gas (20psi) (100 cu. ft.)	Gas (stp) (100 cu. ft.)	
5/22/78	8:00 am	2:00 pm	1	2.4	
	2:00 pm	8:00 pm	11	26.0	
	8:00 pm	2:00 am	0	--	
5/23/78	2:00 am	8:00 am	1	2.4	
	8:00 am	2:00 pm	0	--	
	2:00 pm	8:00 pm	2	4.8	
	8:00 pm	2:00 am	3	7.2	7,380 cubic feet per 72 hours
5/24/78	2:00 am	8:00 am	0	--	
	8:00 am	2:00 pm	1	2.4	
	2:00 pm	8:00 pm	3	7.2	
	8:00 pm	2:00 am	2	4.8	
5/25/78	2:00 am	8:00 am	6	14.2	
	8:00 am	2:00 pm	2	4.8	
	2:00 pm	4:00 pm	26	61.4	

TABLE 6-11
POWER USAGE CALCULATIONS

SYSTEMS	VOLTS (V)	AMPS (A)	OPERATING TIME-HRS. (T)	POWER USED KW-HRS. $\left(\frac{VxAxT}{1000}\right)$ x 1.384 = KW-HR. (1.384 = Power Factor x 1.73)	POWER USED BTU (KW-HR. x 3413)
Hydraulic	480-3Ø	10	22.1	146.81	$.5011 \times 10^6$
Left BB	"	4.4	90.17	263.57	$.8996 \times 10^6$
Left LBC	"	4.0	60.83	161.64	$.5517 \times 10^6$
Left UBC_1	"	5.0	90.17	299.51	1.0222×10^6
Left UBC_2	"	5.4	90.17	323.47	1.1040×10^6
Right UBC_1	480-3Ø	4.2	90.17	251.59	$.8587 \times 10^6$
Right UBC_2	"	4.2	90.17	251.59	$.8587 \times 10^6$
Right BB	"	4.4	90.17	263.57	$.8996 \times 10^6$
Right LBC	"	4.5	53.0	158.44	$.5408 \times 10^6$
Asp. Fan	"	24.0	89.2	1422.18	4.8539×10^6
Cont. Ash Conv.	"	2.8	90.17	167.72	$.5724 \times 10^6$
Air Comp.	"	18.0	44.4	530.92	1.8120×10^6
			Total	4241.01	14.47×10^6
			Total/Hour	47.03 $\frac{\text{KW-HR.}}{\text{HR.}}$	$.1605 \times 10^6$ BTU/HR

BB - Burner Blower is combustion air to burners - continuous.
LBC - Lower Burner Chamber is underfire air to primary.
UBC - Upper Burner Chamber is excess air to afterburner - contin.

TABLE 6-12
EMISSIONS SUMMARY DATA SHEET

General

Emission Source		Boiler Exhaust Stack			
Date		5/22	5/23	5/24	5/25
Refuse Combusted	(lb)	60080	113500	70400	93000
Refuse Heating Value (AR)	(Btu/lb)	3886	3776	3935	3670
Btu Input (refuse + aux. fuel)	(10^6 Btu/hr)	16.8	14.3	12.0	9.0
Average Steam Load	(lb/hr)	6646	6184	4902	4754

Gas Flow

Stack Area	(ft^2)	10.56			
Avg. Velocity Stack Cond.	(fpm)	2305	2115	2302	1939
Flow Rate at Stack Cond.	(cfm)	24340	22331	24308	20479
Stack Temperature	(°F)	254	253	241	230
Flow Rate at Std. Cond.	(DSCFM)	16548	15088	16829	14321

Emissions

Percent Moisture	(%)	7.9	8.7	8.0	7.9
CO_2	(%)		4.3		
CO	(%)		0.0		
O_2	(%)		17.0		
SO_x	(lb/10^6 Btu)	.22	.23	.48	.27
NO_x	(lb/10^6 Btu)	.34	.45	.46	.36
Fluoride	(ppm)		1.7		
Chloride	(ppm)		17.9		
Cascade Impactor LD_{50}	(μm)	0.7	0.1	0.1	0.2
LD_{95}	(μm)	7.5	2.7	2.5	6.4

		3/22
Particulate Concentration	(gr/SCF)	.029
Corrected to 12 Percent CO_2	(gr/SCF)	.100
CO_2	(%)	3.5

6.5 Electric Consumption

The electrical consumption was minimal and totaled approximately .16 million Btu per hour as compared to a total refuse input of 12.1 million Btu per hour. This data is detailed in Table 6-11.

6.6 Emissions

While emissions are a small portion of this study, they were monitored daily. All the emissions data was collected at the boiler exhaust stack. There were no tests run on the dump stack. The data is summarized in Table 6-12.

The stack gas velocity and temperature were measured to establish total flow rates, for an averaged result of 15,700 scfm stack gas flow. The average stack moisture was 8.1 percent and was reasonably stable despite fluctuations in refuse moisture. This is to be expected since the refuse moisture is only about 30 percent of the total stack moisture. The method of particulate analysis in May was questionable. A previous set of tests conducted at this site during the week of March 22, 1978 show a particulate loading of .029 grains per standard cubic foot. Corrected to 12 percent carbon dioxide, these emissions are .100 grains per standard cubic foot. This is half of the acceptable level per the Arkansas Air Pollution Control Code as amended January, 1972.

SO_x was monitored on a daily basis, the average was .3 pounds per million Btu. The nitrous oxide was monitored on a daily basis with an average of .4 pounds per million Btu. Flouride and chloride were also monitored as an indicator of the acid generating

potential of the stack emissions. Fluoride was observed to average 1.7 parts per million and the chloride was observed to average 17.9 parts per million.

Cascade impaction was utilized to determine the particulate size distribution. The results indicated that 50 percent of the particles were 2.8 microns or smaller and that 95 percent were 4.7 microns or smaller. There was no soot blowing scheduled during the emissions tests.

6.7 Downtime

Downtime was kept to a minimum during this test. There was about two hours downtime on Monday due to a fan belt problem on the only operating front-end loader. Tuesday saw about two hours down due to a maintenance error; i.e., the hydraulic system was accidently drained while trying to fix a small leak. The front-end loader went down for about an hour again Wednesday. There was a 15 minute downtime Thursday due to unknown causes.

6.8 Maintenance

Maintenance was not a large problem during the test period. The primary exception being the front-end loader, which was not supposed to be part of the test. Other than that, there were some lights that didn't function. The incinerator loading door needed an assist once or twice. The truck scale malfunctioned about seven minutes. All of this served to attest to the need for a full-time operator. The equipment which was tested was "second generation" equipment in that a number of changes were made to match the operator's desires.

APPENDIX A

Environmental Engineering Services Corporation
ESCOR

Crossville, Tennessee
October, 10, 1977

Unit Identification:	Farrier Incinerator with York Shipley triple pass fire tube boilers. Two Units.
Operation:	Accepts 30 tons of refuse per unit per day. Operates 5 days per week, 24 hours per day. Startup scheduled for January, 1978.
Fuel:	25 percent shredded rubber. 25 percent wood, paper, and cardboard. 50 percent mixed municipal refuse.
Output:	Steam 18,000 pounds per hour, 150 psi.
Incinerator:	This unit is started with natural gas or fuel oil. There are no rams in this system. The refuse is injected with a "ball screw actuator", which also moves the ash through the unit to the ash pit where it falls onto the water trough. A slat conveyor moves the ash to the dumpster. Refuse injection is based on afterburner temperature (1500°F). Underfire air is supplied through slots in the primary floor. Overfire air is supplied through the auxiliary burner port. There are no water sprays to control over temperature. It is estimated that only 14 gallons of oil will be required each week for startup.
Afterburner:	This uses natural gas or fuel oil. Air is modulated by an oxygen analyzer. Temperature out is estimated to be 2200°F to 2400°F.
Boiler:	There is no soot blowing capability. Induced draft fans move the flue gas through the boiler. There is no condensate return.
Emissions:	No problems expected.
Cooperation:	Very cooperative.

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John Deere Corporation

Dubuque, Iowa
September 1, 1977

Unit Identification: Consumat Model CS 1200 With CRS805 Steam Modules.

Operations: The installation started May 1, 1977. There is one more month of debugging required. There are three identical units. The units operate 12 hours per day at one ton per hour.

Fuel: Type O refuse which is high in combustibles, with a little glass and metals.
There is a steady supply.
A pellet shredder is used to preprocess pallets.

Output: The steam is used for process and space heat. It supplies only 5 percent of the plant needs.

Incinerator: The ash is primarily green with pieces of paper.
The unit is started with waste oils.
The refuse is injected from a below floor pit on a timed cycle.
This is a four (4) ram system:
- One ram injects the refuse on a manually initiated automatic cycle.
- Two internal rams move the refuse through the unit and support the four underflow air tubes.
- One ram moves the ash past the water sprays into the ash pit. Continuous water flow was substituted to quench the ash. The timing is independent of the feed.

Primary chamber temperature is monitored in the roof two feet from the outlet, and controls the primary water spray. Water spray operates at 1400°F.
Underfire air is supplied through the four tubes on the internal rams.
Overfire air is not supplied.
All the supplied air comes from outside the building through insulated ducts.

Afterburner: The waste fuel oil is backed up with fuel oil.
There are two excess air blowers.

Boiler:	The boiler starts making steam at 900°F, and the dump stack automatically operates at 1800°F. The steam is generated in deep fin tubes, at 24 psig. The soot blower operates every five minutes on a section of the boiler tubes. The condensate is well water, which is decalcinated, has caustics added, preheated, and deaerated. All return condensate goes to the primary powerhouse. Blowdown is automatic according to the conductivity. The maximum blowdown is 20 percent. There is no insulation on the ductwork and the skin temperature is approximately 250°F. An aspirator pulls the flue gas through the boiler using air from outside the building.
Emission:	Unknown
Cooperation:	Not likely to allow use for test.

North Little Rock Municipal Incinerator — North Little Rock, Arkansas, September, 1977

Unit Identification:	Consumat Model CS-1200 with a CRS-1005 boiler. Two incinerators per boiler.
Operation:	They will complete installation during the month of September, 1977. They will burn the first refuse the week of 9/6/77 in one incinerator. On September 15, both units will be operating, and on October 15, all four units will be on solid waste. The plant will operate 24 hours per day guaranteed to supply process steam to the Koppers Creasote Plant. The plant has a capacity of 100 TPD refuse.
Fuel:	Steady supply all residential refuse to start with. A truck scale is being installed so the plant can accept commercial refuse in the future. There is a backup supply of wood fuel from Koppers.
Output:	Steam 15,000#/hr, 110-115 psig.
Incinerator:	The unit is started up with natural gas or fuel oil. The refuse is injected from a below floor pit on a timed cycle. This is a four (4) ram system: One ram injects the refuse on a manually initiated automatic cycle. Two internal rams move the refuse through the unit and support the four underfire air tubes. One ram moves the ash into the water-filled quench tank where a drag out conveyor can move it into a dumpster. Eight cubic yards per day of ash is expected. Primary chamber temperature is monitored on the roof with normal operating temperature of 1600°F. Underfire air is supplied through the four tubes attached to the internal rams. The rams are 3 inch diameter with 10 to 12 holes in each. A single fan supplies all

	the tubes. The air supply stream is directed towards the refractory bottom of the primary chamber. Overfire air is not supplied. There are three primary chamber water sprays on temperature controllers.
Afterburner:	The afterburners use gas or fuel oil. There are two excess air supply fans.
Boiler:	The flue gas from two incinerators pass through two refractory doorways into a single boiler. The boiler tubes are straight at the entrance and fin tubes at the exit. The soot blower operates with compressed air. An aspirator pulls the flue gas through the boiler. The dump stack has a hydraulic damper. The water is softened and deaerated. 50 percent condensate return is expected.
Emissions:	Expected to be good.
Cooperation:	Expect good cooperation.
Miscellaneous:	Roger Williams, President of Koopers is cooperative. Arkansas has a rule: industry gets high priority for gas and oil if they produce more energy than they use. Consumat was chosen because they have ten operating units. The present landfill tipping fee is five dollars ($5.00) for an eight cubic yard truck.

Rockwell International Corporation — Marysville, Ohio, September 1, 1977

Unit Identification:	Kelley/Hoskinson Model 1280 York-Shipley Hot Water Heat Exchanger
Operation:	Installed 1977. Operating schedule: 16 hours per day, 2 shifts. Minimum operation in Spring and Fall. The units are used for heating and air conditioning and humidity control to prevent rust. 4-40 yd^3 compactors per week.
Fuel:	80-90 percent wood by <u>weight</u>, with computer-paper, dunnage, 50 acres of corn stalks, oil wash from paint booth, etc. as available. There is a steady supply of refuse. Wood is stored for use in the winter or peak time. There is no weigh station available.
Output:	Hot water for heating and absorption air conditioning and humidity control (prevent rust). This unit supplies energy for average but not max load. It supplies nine roof top air conditioning units. It can save 1500 mcf natural gas during winter or 4 x 10^6 Kw-hr of electric during summer.
Incinerator:	It is started up with fuel oil. There is single ram injection and ash movement in the incinerator, which operates on a timed cycle. The underfire air comes through slot holes in the bottom of the main chamber. Overfire air is not included. Chamber temperature is monitored at the roof level. The flue gas outlet is near the end of the unit. The temperature controlled water spray is frequently on. Ash is pushed through the spray chamber onto the dumpster conveyor by a second ram with a heat resistant tip.

Afterburner:	Temperature is regulated. It burns fuel oil with no air control.
Boiler:	Flue gas passes through 15 feet of duct into the multipass fire tube boiler. The boiler has a typical inlet temperature of 1600°F. The ID fan pulls the gas into the boiler. There is a bypass damper in the combination dumpstack and boiler exhaust.
Emissions:	EPA approved this unit without test.
Cooperation:	Willing to test.

Pentagon

Washington, D.C.
September 8, 1977

Unit Identification:	Consumat CS-1000 with CRS-804 steam module.
Operation:	Installed July 1976, full operation January 1977. Operating schedule - eight hours per day, five days per week. 25 percent of steam for Pentagon use. 10,000 pounds of paper is incinerated per day. 250 pound hoppers are manually loaded on a timed basis; for loose paper the cycle is 7 minutes; for plastic the cycle is 10 minutes.
Fuel:	Primarily paper: classified, top secret, etc.; plastic viewgraph, film, and microfilm. There is no steady supply. The fuel can be weighed by a 19" x 24" platform scale.
Output:	Steam 6,000 #/hr, 135 psi. The steam is used for spaceheating. Ash is white. It is burnout overnight, and unloaded once per day.
Incinerator:	It is started with fuel oil. This is a three ram system: One ram injects the refuse based on a timed cycle. The automatic fire door and ram operation is manually started. The ram inside the unit supports the underfire air tubes and moves the ash to the ash pit. The ash ram moves the ash into the water bath once a day so the chain slat ash conveyor can move it to a dumpster. There is water sprayed on the automatic fire door to prevent flashback. The water spray's are temperature controlled. The underfire air enters through floor holes as well as through the middle ram air tubes. There is no overfire air.

Afterburner:	Fuel oil is used freely to insure complete destruction. It is continuously operated until five hours after the last load. There are two fans for air. There is no cap on the dump stack.
Boiler:	When the flue gas is at 600°F, the unit can start making steam. When the flue gas reaches 1600°F, the quench water starts. There are eight banks of steam pipes. The soot blower is on a 30-60 minute automatic cycle. Condensate is returned only to the main power plant. Blowdown is daily. There is no damper on the dumpstack. There is an aspirator downstream of the boiler, and a damper.
Emission:	The emissions are 1/2 to 1/3 of EPA regulations.
Cooperation:	Willing to test.

Diamond International Corporation — Groveton, N. H.
September 7, 1977

Unit Identification:	Environmental Control Products Model 2500T.
Operation:	Installed in 1975, 1 1/2 years of full operation. 24 hours per day, 5 1/2 days per week. 2 cubic yards per 45 minutes.
Fuel:	There is a steady refuse supply. 4 1/2 days per week - mill pickup, sawdust, pallets, grit. 1 day per week - municipal waste, restaurant waste.
Output:	Process steam 3000 to 4000 pounds per hour, 125 psi. This unit is rated at 7000 to 8000 pounds per hour. White ash. It supplies supplemental steam to their main power plant. It is not a necessary source.
Incinerator:	There is a conveyor to the charging hopper. There is no weigh scale. It is started with fuel oil. This is a two ram system: One ram injects the refuse when the primary temperature is below 2000°F. One interior ram moves the ash into the pit. There is no cooling on this ram except "wet ash". There is no separate ash ram. The ash is spray quenched when it falls onto the metal bed of the drag conveyor. There is no quench water in the main chamber; the temperature is controlled by refuse feed control and underfire air modulation. Underfire air enters through eight holes on both sides of the first level and through the back hole. The air is manually controlled. Overfire air enters at the exit of the primary and is also manually controlled with a damper. Ash is manually removed when the level is met in the site glass. The primary is cleaned weekly; the secondary every five weeks.

Afterburner:	This unit burns fuel oil. The burners are controlled from the primary temperature. The burners use no oil with dry wood or trash, and have run two weeks without using any oil. There are some burner problems since there are no damper air controls (air/fuel ratio). There is no damper on the dumpstack.
Boiler:	This is a one pass fire tube boiler. During our visit, the temperature in was 1400°F and the temperature out was 400°F. There is an ID fan and manual damper downstream of the boiler. There are no soot blowers. The tubes are manually cleaned weekly. All condensate is returned to the main powerhouse. Ash is manually removed, water sprayed, then conveyed to the disposal truck.
Emission:	There are none visible. The unit was not tested.
Cooperation:	Willing to test.

Moore Business Forms Corporation — Honesdale, Pennsylvania
September 8, 1977

Unit Identification:	Comptrol Model A45
Operation:	Installed February, 1977. Operating schedule: 24 hours per day, 7 days per week. Load rate 1000# paper per hour of computer forms and design forms.
Fuel:	Refuse, predominately paper with 8500 plus Btu/hour heating value. There is a steady supply of refuse which is stored nearby. There is a weigh station at the boiler. Soon unbroken bales will be input to the unit. The refuse is input on a timed basis.
Output:	Process steam. They use half the available production and dump the rest. The ash is white during optimum performance.
Incinerator:	The unit is started with gas or oil. The startup burner doesn't work well. There is a single ram to inject and move the ash through the unit. The unit is loaded when the primary temperature is between 1800°F and 2000°F. There is a water spray on the inlet door to prevent flashback. Underfire air enters through slots on the primary floor. There are five extra air inlets at the ash pit. The air is not modulated. Overfire air enters above the inlet door, through six, two-inch holes. This is on when the temperature is between 2200°F and 2400°F. Ash is dumped on a four hour cycle, water sprayed, and conveyed to a dumpster. The primary floor is inclined to breakup the ash. The primary temperature can be maintained with paper alone, but burnout is poor.
Afterburner:	This unit burns fuel oil or gas in a two level burner. Low fire is below 1800°F. There are no excess air fans.

Boiler:	This is a single pass fire tube boiler. The unit starts producing steam at 1800°F after a two hour preheat. Boiler pressure controls the ID fan and dump valve. There is a high percent of condensate returned. Feedwater is treated at this site. Blowdown is daily. The ductwork is insulated. Routine maintenance is on a three week schedule. The boiler has not been cleaned since startup.
Emission:	State approved this unit without a test.
Cooperation:	Would probably cooperate in a test.